electric motor. The use of the materials also gives significant advantages in weight reduction, conformability, deformability, and reaction speed to a detected force.

[0040] It is noted that the terms electractive, polymer, piezoelectric material, electrostrictive, magnetostrictive material may be used interchangeably to describe the aforementioned dynamic materials. However, it is noted that these descriptions are not exclusive. In addition, these descriptions may likewise be further subdivided into various categories. Electroactive polymers/electrostrictive materials, for example, may be subdivided into three types: 1) electronic (driven by electric forces involving the movement of electrons), 2) ionic (consisting of electrodes and elcetrolytes and involving the movement of anions/cations), and 3) molecular (exemplified by, but not limited to, carbon nanotubes).

[0041] The brace **80** is an example of such an adjustable orthotic brace and comprises an element of a dynamically variable brace system **82** illustrated schematically in **FIG. 3**. While the brace **80** is a brace of the type generally suitable for application to a knee, the brace is an example of an adjustable orthotic brace and similar principles may be applied to braces for other joints. Generally, the brace system **82** comprises a bracing element **84** including hinged first **86** and second **88** levers, a plurality of brace attaching elements (e.g., upper and lower cuffs **90** and **92**, respectively, and tensioning structures **94** and **96**), one or more sensing transducers sensing brace parameters, one or more loading transducers to apply force or displacement to the various elements of the brace to vary the characteristics of the brace, and a controller **98** to generate appropriate signals to the loading transducers to alter the brace according to a treatment regimen or in response to a change in a brace parameter sensed by a sensing transducer. In the brace system **82**, the controller comprises generally, a microcontroller **100** including an erasable, programable, read-only memory (EPROM) **102** to store program instructions used to relate brace parameters, including requirements of a treatment regimen and sensed brace parameters, to output signals directing the loading transducers to alter a load applied to or displacement of one or more elements of the brace **80**; random access memory (RAM) **104** to store data and program instructions during processing; and a central processor (CPU) **106** to execute the program instructions and output signals directing action by the loading transducers. The controller **98** typically includes an analog-to-digital convertor (ADC) **108** to convert analog signals output by the sensing transducers to digital data suitable for use by the microcontroller **100**, and a digital-to-analog convertor (DAC) **110** to convert the digital output of the microcontroller **100** to analog signals for operating one or more drivers **112**, **114**, **116**, and **118** operating the loading transducers.

[0042] The brace **80** includes a plurality of sensing and loading transducers to sense bracing parameters and alter one or more characteristics of the brace. The brace **80** includes sensing transducers to measure forces exerted by the attaching elements, including upper **90** and lower **92** cuffs and upper **94** and lower **96** tensioning structures; the angular displacement of the upper **86** and lower **88** levers of the bracing element **84**, and stress in and displacement of the levers **86** and **88**. In addition, the brace includes a plurality of loading transducers to apply force assisting or resisting pivoting of the upper **86** and lower **88** levers, deflect the bracing element **84** substantially normal to the limb to alter compartmental loading of the joint, and to alter force exerted by the attaching elements **90**, **92**, **94**, and **96** in binding the bracing element to the limb. As a result, the brace system can dynamically alter the characteristics of the brace **80** to respond to changes in the soft tissue supporting the brace, alter compartmental joint loading, and vary the resistance to joint flexion and extension as a function of, at least, a predefined treatment regimen, joint position, soft tissue conditions, and limb shape. While examples of specific transducer and transducer technologies are specifically described herein, there are a number of other known transducers that can be used to perform the various functions.

[0043] The effectiveness of the brace in controlling the joint is limited by the performance of the elements that bind the brace to the soft tissue of the limb. While displacement of soft tissue cannot be prevented, the exemplary adjustable brace **80** includes sensing transducers **128**, **130**, **132** and **134** to sense parameters related to the interface of the soft tissue and the attaching elements and loading transducers **120**, **122**, **124**, and **126** to adjust the attaching elements according to a treatment regimen or the changing characteristics of the interface between the brace and the soft tissue. For example, as the joint is flexed, the dimension and tone of the muscles change. As a result, the force binding the limb to the bracing element and the effectiveness of the attaching elements in resisting brace movement and controlling the joint varies. The attaching elements of the adjustable brace **80**, the upper thigh **90** and lower tibial **92** cuffs and the tensioning structures **94** and **96**, include sensing transducers to detect changes in the tension of the bindings and loading transducers to alter the attaching elements to maintain an optimal restraining force. **FIG. 4** illustrates an exemplary attaching element **150** for an adjustable brace that includes an exemplary sensing transducer **152** to detect the tension in a binding **154** and a loading transducer **156** to alter the tension in response to signals from the controller **98**. The attaching element **152** includes a cuff base **158** formed from a plastic covering of the bracing element **84** and a binding **154** that encircles the limb and is attached to the cuff base at each end. The binding **152** is attached to the cuff at a first end **160** by passing the binding through an elongated eyelet **162** in the plastic cover, folding the end back onto the binding, and attaching the end to the body of the binding with complementary hook and eye material or a buckle. The second end of the binding **154** is attached to the cuff **158** by passing the end of the binding through a ring **164**, folding the end back, and sewing the end to the binding. The sensing transducer **152** comprises an instrumented link that attaches the binding **154** to the cuff **158**. The ring **164** bears on an electrostatic polymer transducer or piezoelectric transducer **166** that is attached to a mounting block **168**. The mounting block is riveted **170** to the plastic cuff **158**. Tension in the binding **154** exerts a force on the ring **164** causing the piezoelectric transducer **166** to be compressed. It is to be understood that alternatively the piezoelectric materials (sensors and/or actuators) may be any suitable material, such as for example, electroactive polymers (e.g., ionic, electronic, and molecular electroactive polymers). Some electroactive polymers include active gels, electrorestrictive polymers, carbon nanotubes, magnetorestrictive polymers, dielectric polymers and elastomers, liquid crystal elastomers, and ionic polymer metal composites.